

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE**NUMBER: 03-1-0435 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 1 02/22/01**PART DATA**

PART NAME	PART NUMBER
VENDOR NAME	VENDOR NUMBER
LRU : FLAME ARRESTOR, LH2 BOEING	V070-415430-006

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

FLAME ARRESTOR, LH2, 1.8 INCH DIAMETER.

REFERENCE DESIGNATORS: FL1**QUANTITY OF LIKE ITEMS:** 1**FUNCTION:**

THE FLAME ARRESTOR IS LOCATED AT THE LH2 VENT LINE OUTLET BETWEEN THE BASE OF THE VERTICAL STABILIZER AND THE LEFT OMS POD. THE DEVICE PREVENTS EXTERNAL FLAME (FROM RELIEF SYSTEM) FROM PROPAGATING BACK INTO THE LH2 VENT SYSTEM.

FOR NOMINAL, ATO, AOA, AND TAL MISSIONS, GH2 VENTING OCCURS AFTER MECO WHEN THE MANIFOLD RELIEF SHUTOFF VALVE (PV8) OPENS. AFTER COMPLETION OF PROPELLANT DUMP AND VACUUM INERTING NO ADDITIONAL VENTING IS EXPECTED FOR NOMINAL, AOA, AND ATO MISSIONS. FOR RTLS AND TAL MISSIONS, GH2 VENTING OF LH2 RESIDUALS IS EXPECTED POST LANDING.

FAILURE MODES EFFECTS ANALYSIS FMEA -- CIL FAILURE MODE

NUMBER: 03-1-0435-02

REVISION#: 1 02/22/01

SUBSYSTEM NAME: MAIN PROPULSION

LRU: LH2 FLAME ARRESTOR

ITEM NAME: LH2 FLAME ARRESTOR

CRITICALITY OF THIS

FAILURE MODE: 1R3

FAILURE MODE:

CLOGGED

MISSION PHASE: LO LIFT-OFF

VEHICLE/PAYLOAD/KIT EFFECTIVITY:	102	COLUMBIA
	103	DISCOVERY
	104	ATLANTIS
	105	ENDEAVOUR

CAUSE:

CONTAMINATION, CORROSION

CRITICALITY 1/1 DURING INTACT ABORT ONLY? YES

RTLS	RETURN TO LAUNCH SITE
TAL	TRANS-ATLANTIC LANDING

REDUNDANCY SCREEN

- A) PASS
- B) N/A
- C) PASS

PASS/FAIL RATIONALE:

A)

B)

FLAME ARRESTOR IS STANDBY REDUNDANT TO LH2 SYSTEM FAILURE REQUIRING RELIEF.

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

NO EFFECT NOMINAL, ATO, OR AOA. POSSIBLE FIRE/EXPLOSION HAZARD FOR RTLS/TAL ABORTS DUE TO VENTING POST-LANDING. POSSIBLE LOSS OF CREW/VEHICLE.

(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0435-02**

(C) MISSION:

NO EFFECT FIRST FAILURE. POSSIBLE LOSS OF CREW/VEHICLE FOR RTLS/TAL ABORTS.

(D) CREW, VEHICLE, AND ELEMENT(S):

SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:

1R/3 3 SUCCESS PATHS. TIME FRAME - LH2 DUMP.

- 1) CLOGGED FLAME ARRESTOR (FL1).
- 2) EITHER RTLS DUMP VALVE (PV17 OR PV18) FAILS TO OPEN/REMAIN OPEN POST-MECO.
- 3) OUTBOARD FILL & DRAIN VALVE (PV11) FAILS TO OPEN/REMAIN OPEN, LH2 MANIFOLD PRESSURE TRANSDUCER FAILS SUCH THAT SOFTWARE AUTO DUMP SEQUENCE IS NOT INITIATED OR DUMP SWITCH FAILS IN "STOP" PREVENTING INITIATION OF LH2 DUMP.

RESULTS IN LACK OF RELIEF CAPABILITY. POSSIBLE RUPTURE OF THE LH2 MANIFOLD CAUSING LH2 LEAKAGE INTO AFT COMPARTMENT, OVERPRESSURIZATION, AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYOGENIC EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:

VENTING IN THE ATMOSPHERE FROM THE LH2 FEEDLINE RELIEF MAY RESULT IN COMBUSTION. THE FLAME ARRESTER PREVENTS THE RESULTING FLAME FROM PROPAGATING BACK INTO THE ORBITER LH2 PLUMBING. THE ARRESTER CONSISTS OF FOUR PARTS: A HOUSING THAT CONTAINS TWO DISCS THAT ARE SEPARATED BY A SPACER. EACH 304 CRES DISC HAS A 1.750 INCH O.D., IS 0.500 INCHES THICK, AND CONTAINS APPROXIMATELY SIX THOUSAND 0.017 INCH DIAMETER HOLES THROUGH THE THICKNESS. IF FLAME ATTEMPTS TO PASS THROUGH THE DISC, ITS TEMPERATURE IS REDUCED BELOW THE THRESHOLD OF FLAMMABILITY AND IS QUENCHED. THE SECOND DISC IS REDUNDANT.

CLOGGING DUE TO ICE FORMATION IS HIGHLY UNLIKELY. IN THE JSC TESTING (SEE TEST BELOW) IT WAS IMPOSSIBLE TO SUSTAIN A CLOGGED CONDITION DUE TO ICE FORMATION AFTER REPEATED ATTEMPTS.

SYSTEM CONTAMINATION IS MINIMIZED DUE TO THE PRESENCE OF AN ET SCREEN, A GSE DEBRIS PLATE, AND A GSE FILTER.

CORROSION PREVENTION IS GUARDED AGAINST BY PASSIVATION OF ALL PARTS. DURING GROUND TURNAROUND THE FLAME ARRESTER IS SUPPLIED WITH A PROTECTIVE COVER.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0435-02**

(B) TEST:

ATP

DISC
FLOW TEST (19 PSIA IN AND 4 PSID MAXIMUM):
 AMBIENT: 0.28 LB/SEC GN2

ASSEMBLY
 AMBIENT PROOF (300 PSIG)
 LEAK TEST (150 PSIG)

VERIFICATION

IGNITION TESTING

NINETY-THREE IGNITION TESTS SUCCESSFULLY CHARACTERIZED THE PERFORMANCE OF THE FLAME ARRESTER DESIGN DURING NORMAL AND ADVERSE CONDITIONS. FACTORS MONITORED DURING TESTING WERE PRESSURE DROP, FLAME ARRESTING CAPABILITIES, PLUME CHARACTERISTICS, AND GAS TEMPERATURE EFFECTS ON THE ARRESTER.

VARIED PARAMETERS:

GH2 FLOW (FROM .005 TO .022 LB/SEC)
GH2/AIR FLOW-AIR/FUEL RATIO OF 40 (.005,.010,.020 LB/SEC GH2)
GAS TEMPERATURE (-200 DEG F, AMBIENT, +200 DEG F)
IGNITION ON (BEFORE AND AFTER FLOW INITIATION).
WIND -
 NONE
 200 KNOTS @ 45 DEG TO FACE
 200 KNOTS NORMAL TO THE ARRESTER FACE)

ICING TESTS

NASA/JSC CONDUCTED A SERIES OF TESTS TO DETERMINE IF THE ARRESTER COULD BE CLOGGED BY ICE DUE TO THE ORBITER LANDING IN RAIN. BOILOFF GAS FROM A LH2 DEWAR WAS VENTED THROUGH THE ARRESTER (MOUNTED WITH ITS CENTERLINE VERTICAL). AFTER THE ARRESTER WAS THOROUGHLY CHILLED, WATER WAS SPRAYED (THROUGH A MISTING NOZZLE) ONTO THE EXPOSED SURFACE OF THE OUTER DISC, AND THE SURFACE FROZE OVER.

TEST RESULTS WERE:

- FLOW STOPPED DUE TO THE ICING. DUE TO LACK OF CRYO FLOW, THE TEMPERATURE OF THE ARRESTER INCREASED TO THE MELTING TEMPERATURE OF THE ICE.
- MAXIMUM UPSTREAM PRESSURE INCREASE DUE TO THE STOPPED FLOW WAS APPROXIMATELY 60 PSID.
- UNDER THESE CONDITIONS, A PORTION OF THE ICE BLEW OFF, FLOW WAS REESTABLISHED, AND THE AREA ADJACENT TO THE FLOW RECHILLED. AFTER A FEW SECONDS, THE REMAINDER OF THE ICE BLEW OFF. IT WAS

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0435-02**

THEORIZED THAT THE REESTABLISHED FLOW CREATED A TEMPERATURE GRADIENT WITHIN THE ICE CAUSING IT TO FRACTURE.

OMRSD

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

(C) INSPECTION:

RECEIVING INSPECTION

RAW MATERIALS ARE VERIFIED BY INSPECTION FOR MATERIAL AND PROCESS CERTIFICATION.

CONTAMINATION CONTROL

CONTAMINATION CONTROL PROCESS AND CORROSION PROTECTION PROVISIONS ARE VERIFIED. CLEANLINESS TO LEVEL 400 IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

DETAIL PARTS ARE FABRICATED TO DRAWING SPECIFICATIONS AND VERIFIED BY INSPECTION. CORROSION PROTECTION AND SEALING SURFACES PROTECTION ARE VERIFIED. AT THE DETAIL LEVEL, THE DISCS ARE TESTED FOR FLOW, PRESSURE DROP, AND CLEANLINESS REQUIREMENTS. DIMENSIONS AND TOLERANCES ARE VERIFIED.

CRITICAL PROCESSES

HEAT TREATMENT, WELDING, AND BRAZING ARE VERIFIED. PARTS PASSIVATION AND ELECTROPOLISHING ARE VERIFIED BY INSPECTION. ELECTRICAL BONDING AND TEST (SYSTEM INSTALLATION) PER MAO113-306 CLASS L TYPE I IS VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

RADIOGRAPHIC INSPECTION OF INDUCTION BRAZES IS VERIFIED BY INSPECTION. PENETRANT INSPECTION IS VERIFIED.

TESTING

ATP IS VERIFIED BY INSPECTION.

HANDLING/PACKAGING PACKAGING FOR SHIPMENT IS VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:

GENERAL SYSTEM CONTAMINATION

GENERAL MPS SYSTEM CONTAMINATION HAS OCCURRED WHICH MAY LODGE ANYWHERE IN THE SYSTEM CAUSING THIS FAILURE MODE (REFERENCE THE FOLLOWING PARAGRAPHS).

CONTAMINATION FAILURES HAVE OCCURRED AT ALL PHASES OF MANUFACTURING AND PARTS REPLACEMENT. IN ALL CASES, STRICT ADHERENCE TO CLEANLINESS CONTROL PROCEDURES IS THE PRIMARY METHOD OF CONTAMINATION PREVENTION.

NUMEROUS LARGE PARTICLES OF BLACK RUBBER MATERIAL WERE FOUND DURING A POST FLIGHT EXAMINATION OF THE LH2 17 INCH DISCONNECT OF OV099 (FLIGHT 7, REFERENCE CAR AC9800). THE LO2 AND LH2 SYSTEMS OF ALL VEHICLES WERE

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0435-02**

EXAMINED. NO RUBBER WAS FOUND IN ANY OTHER VEHICLES. AFTER EXTENSIVE INVESTIGATION THE ORIGIN WAS NOT DETERMINED.

METAL SHAVINGS HAVE BEEN DISCOVERED IN LINES AND COMPONENTS, WHICH WAS MOST LIKELY GENERATED WHEN THEY WERE CUT OUT AND/OR REPLACED (REFERENCE CARS AC9868, A9654, AC2210, AB1706; DR AD2226). METHODS HAVE BEEN REVISED TO MINIMIZE PARTICLE GENERATION WHEN INSTALLING/REPLACING COMPONENTS, LINES, AND FITTINGS REQUIRING WELDED OR BRAZED JOINTS (PRODUCT QUALITY IMPROVEMENT COUNCIL). PERSONNEL HAVE BEEN CAUTIONED. ROCKWELL PROBLEM ACTION CENTER WILL CONTINUE TO MONITOR BRAZING/WELDING REWORK CONTAMINATION. PROCEDURES HAVE BEEN REVISED TO IMPROVE CLEANLINESS MAINTENANCE DURING COMPONENT BUILD UP AND REWORK (REFERENCE MCR 12512). SUPPLIER DOCUMENTS/PROCEDURES HAVE BEEN REVIEWED AND CLEANLINESS MAINTENANCE PROCEDURES HAVE BEEN IMPROVED.

A PIECE OF A BRAZING PREFORM LODGED IN A 2-WAY SOLENOID VALVE ON OV-099 AT PALMDALE CAUSING A LEAKAGE FAILURE (REFERENCE CARS AC2111, AB2538). STEEL AND ALUMINUM PARTICLES CAUSED EXCESSIVE LEAKAGE ON THE 850 PSIG HELIUM RELIEF VALVE (REF CAR AC2229). FOR BOTH FAILURES CORRECTIVE ACTION WAS TO ADD SPECIAL PURGE PORTS TO THE MPS HELIUM PANEL ASSEMBLIES TO IMPROVE THE QUALITY OF FINAL CLOSEOUT BRAZES.

SEVERAL FOREIGN MATERIALS WERE INTRODUCED INTO THE MPS SYSTEM DURING MANUFACTURE AND PARTS REPLACEMENT. EXAMPLES ARE: GLASS CLOTH IN LINE TO PREVENT TRAVEL OF CHIPS DOWN LINE; POLYSTYRENE OBJECT TO HOLD VALVE POPPET OPEN WHILE PURGING; COTTON SWAB MATERIAL AND GLASS BEADS FROM CLEANING OPERATION; MISCELLANEOUS PLASTIC; FOAM; AND TAPE (REFERENCE CARS AB4751, AC2217, AC6768, AC9868, MPS3A0005, AC7912, AB0530). MATERIALS WERE REMOVED AND PERSONNEL WERE CAUTIONED. A HIGH FLOW DELTA P TEST AT PALMDALE WAS ADDED TO VERIFY THAT LINES WERE NOT PLUGGED. GRIT BLASTING (GLASS BEADS AND SAND USED TO CLEAN A LINE) IS NO LONGER PERFORMED. PROCEDURES HAVE BEN REVISED TO IMPROVE CLEANLINESS MAINTENANCE DURING COMPONENT BUILD UP AND REWORK (REFERENCE MCR 12512). SUPPLIER DOCUMENTS/PROCEDURES HAVE BEEN REVIEWED AND CLEANLINESS MAINTENANCE PROCEDURES HAVE BEEN IMPROVED.

ONE PIECE OF WIRE WAS FOUND IN THE INTERNAL RELIEF VALVE OF THE LO2 PREVALVE ON OV103 (REFERENCE CAR AC9101). THE SOURCE OF THE CONTAMINATION WAS NEVER FOUND, BUT IT WAS BELIEVED TO BE FROM THE ET. OTHER CONTAMINATION HAS BEEN FOUND ON THE FEEDLINE SCREENS, SUCH AS AN UNIDENTIFIED ROUND OBJECT AND VARIOUS METALLIC PARTICLES (REFERENCE CARS AB0529 AND AB0530). SOURCE OF CONTAMINATION WAS UNDETERMINED. BORESCOPE EXAMINATIONS ARE CONDUCTED ON ALL FEEDLINE SCREENS EVERY FIFTH FLIGHT TO VERIFY CLEANLINESS. CONTAMINATION WAS REMOVED WHEN POSSIBLE.

CURRENT DATA ON TEST FAILURE, FLIGHT FAILURE, UNEXPLAINED ANOMALIES, AND OTHER FAILURES EXPERIENCED DURING GROUND PROCESSING ACTIVITY CAN BE FOUND IN THE PRACA DATABASE.

(E) OPERATIONAL USE:

LH2 MANIFOLD PRESSURE IS ON CAUTION AND WARNING.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0435-02**

- APPROVALS -

S&R ENGINEERING	: W.P. MUSTY	: /S/ W. P. MUSTY
S&R ENGINEERING ITM	: P. A. STENGER-NGUYEN	: /S/ P. A. STENGER-NGUYEN
DESIGN ENGINEERING	: LEE DURHAM	: /S/ LEE DURHAM
MPS SUBSYSTEM MGR.	: TIM REITH	: /S/ TIM REITH
MOD	: JEFF MUSLER	: /S/ JEFF MUSLER
USA SAM	: MIKE SNYDER	: /S/ MIKE SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	: /S/ SUZANNE LITTLE
NASA SR&QA	: ERICH BASS	: /S/ ERICH BASS